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KANSAS DEPARTMENT OF HEALTH & ENVIRONMENT

FORMATION PRESSURE FALL-OFF TEST AND TESTING PLAN DEVELOPMENT PROCEDURES

Procedure #: UICI-2

SECTION I. PURPOSE

The purpose of this test is to identify injection interval or wellbore problems and injection interval characteristics. It is the responsibility of the permittee to develop a testing procedure which will generate adequate data for a meaningful analysis.

SECTION II. REGULATORY CITATION

KDHE regulation 28-46-30, which references 40 CFR (Code of Federal Regulations) 146.13 (d) and the UIC Permit require monitoring of the pressure buildup in the injection zone at least annually, including at a minimum, shut down of the well for a time sufficient to conduct a valid observation of the pressure fall-off. This test is known as the formation pressure fall-off test.

SECTION III. SCHEDULING OF TEST

The schedule for the test must be mutually agreed upon between KDHE and the permittee so that KDHE has the opportunity to witness the test.

SECTION IV. DEVELOPING A TEST PLAN

A plan for conducting the test shall be submitted to KDHE for review and approval prior to conducting the test. Plan approval shall be obtained from KDHE prior to commencing the test. The plan shall include a proposed schedule. The test plan must address all items listed in the Sections V through VIII of this document.

SECTION V. GENERAL PREPARATION

A review of previous fall-off tests should be conducted to assist in developing a testing procedure that will provide valid test results. This will help prevent repeating any previous mistakes or errors.

A successful test involves consideration of numerous factors of which most are under control of the permittee. These include but are not limited to the following:

1. Adequate storage for the injection liquid needs to be ensured for the duration of the test.

2. Offset wells completed in the same formation as the test well should be shut-in prior to and during the test. If this cannot be accomplished then a low, constant injection rate into the offset injection wells should be maintained prior to and during the test, if feasible.

3. The condition of the well, junk in the hole, wellbore fill or wellbore damage (as measured by skin) may significantly increase the length of time the well must be shut-in to obtain valid fall-off test data. This is especially true for wells completed in low transmissivity reservoirs or which have large skin factors.

4. The location of the shut-in valve to cease flow to the well for the shut-in portion of the test must be located at or near the wellhead. Shut-in must be accomplished as instantaneously as possible to prevent erratic pressure behavior during the test.

5. In most cases the waste liquid can be used unless the waste will be corrosive to the downhole pressure gauge.

6. A surface readout downhole pressure gauge must be used. The capability to produce plots necessary to analyze the test data should be available at the well site to help insure valid test data is obtained and false test runs are quickly identified and aborted. The gauge should be configured to obtain pressure data more frequently in the early portion of the test when the rate of pressure decline is greater. Larger time increments may be used to obtain data later in the test when the rate of pressure decline is less.

SECTION VI. CONDUCTING THE FALL-OFF TEST

The following is the recommended procedure for conducting the test. Alternative procedures that will produce valid test results and which will satisfy the requirements of KDHE and the regulations will be considered by KDHE.

1. The depth to any fill in the well should be tagged and recorded.

2. The surface readout downhole pressure gauge must be located at or near the top of the injection interval, unless previous testing indicates a more appropriate location. A surface readout should be provided to allow flexibility in determining appropriate pressure measuring and recording time intervals and to ensure valid test data is generated and false testing runs can be identified and aborted.

3. The injection rate and injection liquid density for the test must be held constant prior to shut-in. The injection rate must be high enough and continuous for a period of time sufficient to produce a pressure buildup that will result in valid test data. The injection rate must result in a pressure buildup such that a semilog straight line can be determined from the Horner plot. The injection rate should be the maximum injection rate that can be feasibly maintained constant in order to maximize pressure changes in the formation and provide valid test results, but not exceeding the daily injection volume limit of the UIC Permit.

4. The injection rate and the density (chloride concentration, total dissolved solids concentration, conductivity or pH are also acceptable) of the injection fluid must be periodically measured and recorded to insure these parameters remain constant.

5. If the stabilization injection period is interrupted, for any reason and for any length of time, the stabilization injection period must be restarted.

6. The well must be shut-in at the wellhead or as near to the wellhead as feasible in order to minimize wellbore storage and afterflow. The shut-in must be accomplished as instantaneously as possible to prevent erratic pressure behavior during the test.

7. The fall-off portion of the test must be conducted for a length of time sufficient such that the pressure is no longer influenced by wellbore storage or skin effects and enough data points lie within the infinite acting period and the semilog straight line is well developed.

SECTION VII. EVALUATION OF THE TEST RESULTS

A licensed geologist or licensed professional engineer, licensed by the Kansas Board of Technical Professions to practice geology or engineering in Kansas and knowledgeable in the methods of pressure transient test analysis, must evaluate the test results.

The following information and evaluations must be provided with the test report:

1. A log-log plot with a derivative diagnostic plot must be used to identify flow regimes. The wellbore storage portion and infinite acting portion of the test must be identified on the plot. Type curves must be used to verify results.

2. A Horner plot must be used to calculate the kh/u product and to determine P*. An expanded Horner plot containing the entire infinite acting portion must be reproduced in order to permit a closer inspection of the semilog slope and any data fluctuations. The slope used to calculate the kh/u product and to determine P* must be drawn on both Horner plots. In addition, the wellbore storage portion and infinite acting portion of the test must be identified on both plots.

3. The "h" value (injection interval thickness) used must be agreed upon between KDHE and the permittee. For formations with characteristics such as the Arbuckle Formation, the injection interval should be considered the entire thickness of the injection formation in the area. A reliable literature value can be used if site specific data is not available.

4. The viscosity used in analyzing the test must be that of the liquid through which the pressure transient was propagating during the infinite acting portion of the test. The information used to determine the viscosity must be provided.

5. Any test that was not shut-in long enough to develop an infinite acting period, or cannot be properly analyzed for the kh/u group of parameters using the Horner method, should be rerun, using a procedure that will result in valid test results, unless other arrangements have been made with KDHE.

6. All equations used in the analysis must be provided with the appropriate parameters substituted in them.

7. Tests conducted in relatively transmissive reservoirs are more sensitive to the temperature compensation mechanism of the gauge, because the pressure buildup response evaluated is smaller. For this reason, the plot of the temperature data should be reviewed. Any temperature anomalies should be noted to determine if they correspond to pressure anomalies.

8. Explain any anomalous data responses. The analyst should investigate physical causes other than reservoir responses.

SECTION VIII. REPORT COMPONENTS

The report to KDHE must include general information and an overview of the test, present and analyze the test data, summarize the results of the test and compare the results with previous test results. The report shall be submitted to KDHE within 30 days of test completion. The report must include the following:

1. The facility name, location, well identification number and KDHE UIC Permit number of the test well.

2. A well schematic depicting current completion and location of the pressure measuring tool during the test.

3. Test well information including wellbore radius, completed interval and type of completion.

4. The distance between the test well and offset wells completed in the same injection interval and the status of the offset wells during both the injection and shut-in portion of the test. Describe the impact, if any, the offset wells had on the test.

5. Chronological listing of the daily testing activities.

6. A description of the surface readout downhole pressure gauge used including manufacturer and type, resolution, calibration certificate and the manufacturer's recommended frequency of calibration.

7. Date of test.

8. Location of the shut-in valve used to cease flow to the well for the shut-in portion of the test.

9. Time of injection period, type of injection liquid, final injection pressure and temperature.

10. Total shut-in time, final static pressure and temperature.

11. Calculations for the following; including equations used, the equations with the appropriate parameters substituted in them, description of values used in calculations and equations and references for values used:

* Radius of test investigation.
* Time to beginning of the infinite acting portion of the test.
* Horner time to the beginning of the infinite acting portion.
* Slope or slopes determined from the Horner plot.
* The value for kh/u (transmissibility).
* Permeability.
* Skin.
* Pressure drop due to skin.
* Flow efficiency.
* Flow capacity.
* P1hr (pressure at 1hr).

12. Explanation for any pressure or temperature anomaly.

13. Description of whether system is completion or reservoir dominated and whether the system is homogeneous or heterogeneous, including an explanation of how this was determined.

14. The following graphs must be provided:

    * Cartesian plot, pressure and temperature versus time.
    * Cartesian plot of injection rate versus time.
    * Log-Log and derivative plots with the flow regions identified (must identify radial flow).
    * Semi-log Horner and expanded Horner plots with flow regions indicated (must identify radial flow), the semilog straight line drawn, P* (extrapolated pressure) and P1hr (extrapolated pressure at 1hr).

15. A comparison of permeability, Kh/u, skin, P* and fillup with the same values determined from fall-off tests previously conducted.

16. A statement that the raw test data generated by the test will be kept on file by the permittee for a period of not less than 3 years and will be made available to KDHE upon request during this time period. The raw test data need not be submitted to KDHE unless requested.